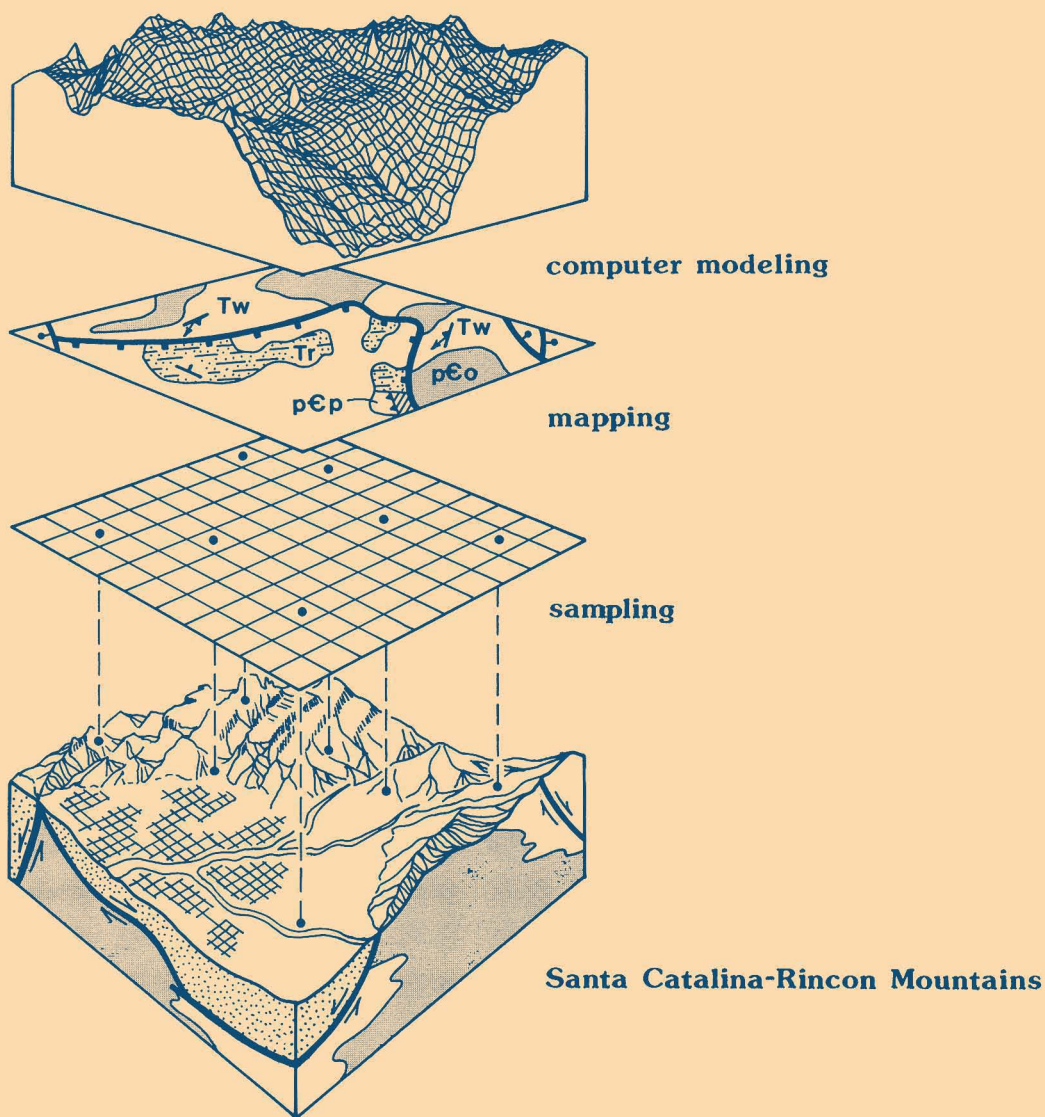


FRONTIERS IN GEOLOGY AND ORE DEPOSITS OF ARIZONA AND THE SOUTHWEST



Edited by Barbara Beatty and P.A.K. Wilkinson



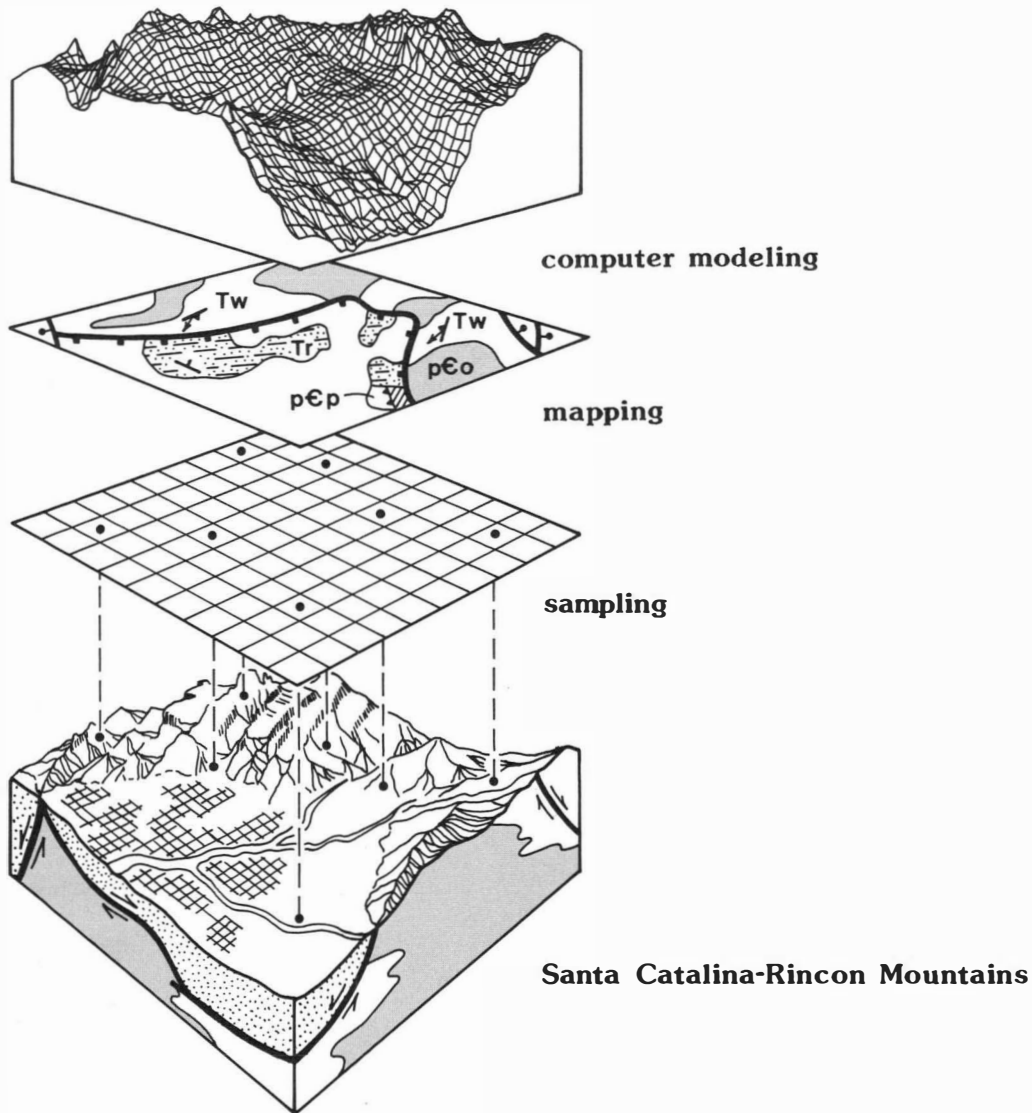
ARIZONA GEOLOGICAL SOCIETY DIGEST VOLUME XVI

Tucson, Arizona

1986

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FRONTIERS IN GEOLOGY AND ORE DEPOSITS OF ARIZONA AND THE SOUTHWEST



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COVER DESIGN by Joy Mehulka, 1022 East Silver Street, Tucson, Arizona 85719 and Paul Mirocha, Office of Arid Lands Studies, University of Arizona, Tucson, Arizona.

Isostatic gravity anomaly plot of the Santa Catalina-Rincon Mountains by C.G. Chase and J. Wang. Computational facilities provided by the Keck Foundation.

Geologic map of the Santa Catalina-Rincon Mountains adapted from maps by Ann Bykerk-Kauffman, University of Arizona, Tucson, Arizona.

EXPLANATION



Tertiary Rillito conglomerates



Tertiary Wilderness granite, mylonitized



Paleozoic sediments



Precambrian Oracle Granite, mylonitized



Precambrian Pinal Schist, mylonitized



strike and dip of bedding



strike and dip of foliation,
trend and plunge of lineation



detachment fault



thrust fault



normal fault

THIS DIGEST IS RESPECTFULLY DEDICATED TO

THE MEMORY OF

EVANS B. MAYO

Teacher and eminent Field Geologist

by

HIS MANY COLLEAGUES, STUDENTS, AND FRIENDS

A TRIBUTE TO EVANS B. MAYO

He would come into class early ... an hour or more early ... even for classes held at 7:30 in the morning. He would cover much of the board with carefully drawn maps, in many colors. Any remaining board space would be filled with tight packed sentences. Commonly he would hold in his hands 5x7 notecards, some with verbatim translations from German (French too) of some of the classic works in structural geology ... translations that would have been unavailable to students were it not for the fact that Dr. Mayo would spend hour upon hour in the library ... translating whole volumes ... without the aid of a dictionary. He was never arrogant, never self-righteous; he was a quietly confident, gentle man. We called him Dr. Mayo, or Professor Mayo simply out of respect. His lectures and seminars were surrounded by a well-read historical appreciation of the flow of science and scientific ideas. There was never presented the illusion that the best work is only being done now. Instead, he presented a mature grasp of the degree to which new ideas emerge from the foundation of past work. He rewarded thoroughness and breadth of understanding. Evans B. Mayo was a scholar.

But he was more than that. He was noted for the exhaustive detail of his mapping and observation. His maps leave nothing to the imagination, even including locations of saguaro and ocotillo as visual references to locations of bedrock relationships. So full of symbols, the maps come alive three-dimensionally, almost as if the folds were folding and the faults were faulting before your very eyes. One unfortunate student, in one of my classes, handed in a tracing of part of an Evans B. Mayo map (that's what we call them) as if it were his own ... not realizing that an Evans B. Mayo map is as distinctive as a Norman Rockwell painting. Evans B. Mayo was a preeminent field geologist.

But he was more than that too. He would most often map with his students, classes of students, shoulder to shoulder, marching and mapping with tape and compass and clipboards across the Tucson Mountains. (There was a time in which he dreamed of being in the military). Such stamina ... seasoned through decades of intensive field work, in jungles, mountains, and deserts. If mapping alone, he would leave at 4 AM. He was comfortable alone, for he wandered alone a lot in the Florida Mountains in his youth near his home on the farm in New Mexico. If mapping with a class -- and he liked this best -- he would show compassion and leave at 6AM and not at 4AM. Lunch was best ... not the lunch itself of course ... but sitting on the sand in a wash, with back to the bank, or holding down a rock (that's what he would say), and comfortably talking, describing, interpreting, and swapping stories the way geologists do. Evans B. Mayo was a teacher, a dedicated teacher, in and outside of the classroom. And his love of the outdoors, his romance with mountains, were contagious.

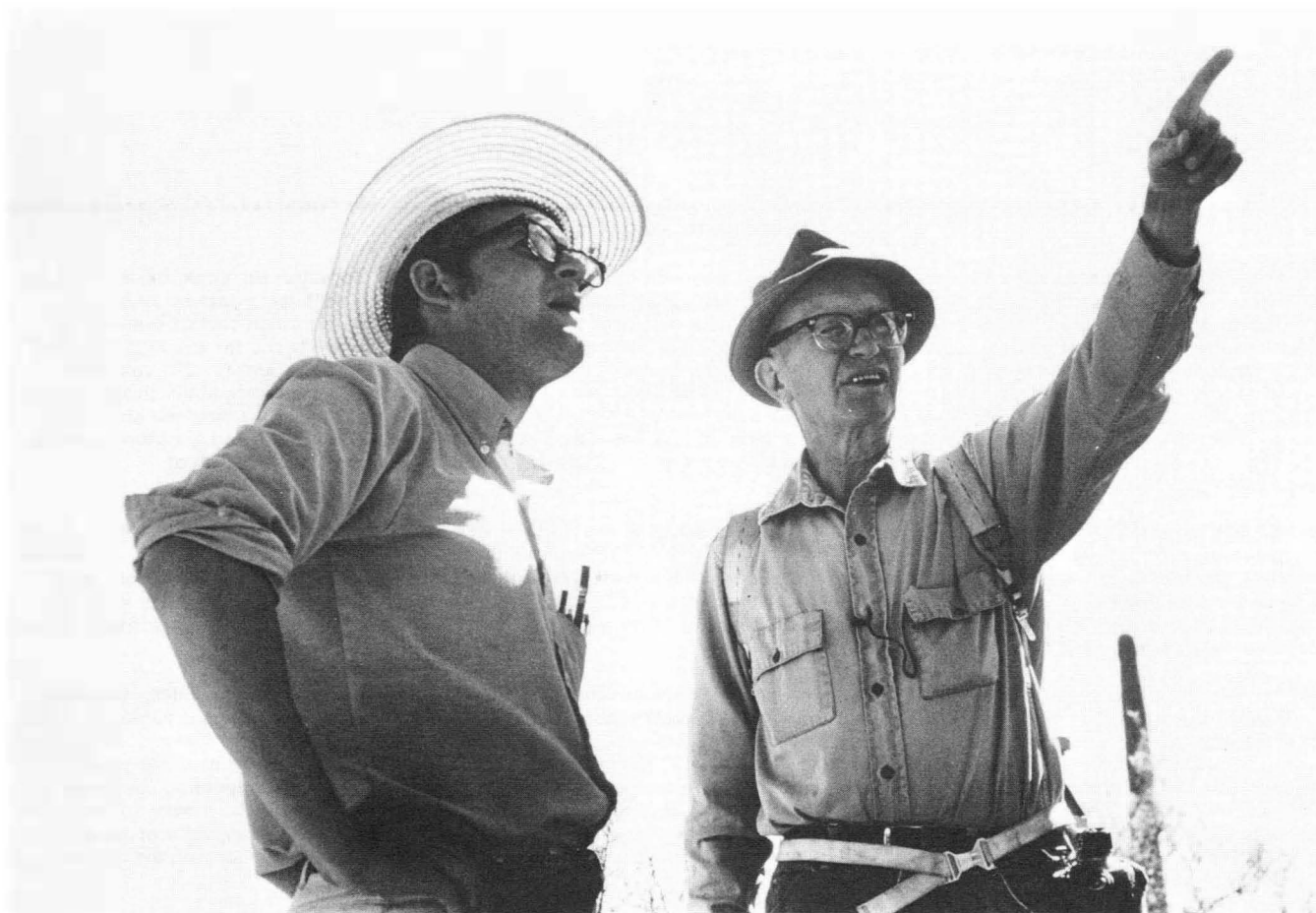
Given who he was and how he lived, some very special relationships developed between this teacher and his students: friendships, loyalties that have held constant in the minds and hearts of his graduates for all these years, and beyond.

I've always felt that Dr. Mayo conducted his life in such an unpretentious way because of his deep respect for the works and grandeur of Nature. By becoming so familiar, first hand, with time, the details of earth history, the subtlety of process, the great forces, he yielded to Nature as the ultimate teacher ... he learned early to follow where Nature led ... to describe all that exists as accurately and as honestly as possible ... and then and only then gaining a glimpse of what it is all about. He did not abide first approximation, or schematic nonsense. He didn't try to impose his prejudices on Nature. And he didn't try to impose dogmatically the force of his thoughts and preferences on his students, or on his successor. Evans B. Mayo was quite a scientist, and scientific advisor.

But there is more, more than could ever be recounted here. Maybe in this eulogy I should be listing his degrees, his publications, his honors ... of which there are many. There is no need. Our lives are our statements. His life is his statement. And Dr. Mayo's statement is crystal clear to all who knew him. To his children he offered the rich childhood experiences of living and growing up in extraordinary places like the tropics of Ecuador, a ghost town in British Columbia, and in the university setting here in Tucson as well; and with his children, and his grandchildren, he shared his love and understanding of Nature during backpack and camping trips in the Sierras.

In all respects, Dr. Mayo has shown that life, and how we live it, does make a difference. We feel the loss, a deep sense of loss ... but that is the way we would want it to be.

George H. Davis
January 8, 1986



"THE TRUTH IS HARD TO COME BY"

I inherited this statement many years ago from Augustus Locke of Menlo Park, California. It seems to apply with particular force to geology. There seem to be several reasons for this, among them:

- The immense size of geological features as compared with the infinitesimal geologist. Now-a-days we have many mechanical aids, but there is no satisfactory substitute for examination at the outcrop.
- The vertical dimension is often not exposed, and can be studied only by use of the drill, in quarries, mine workings, or by the indirect methods of geophysics.
- Surface exposures are seldom complete and they can be very limited indeed.
- Nature places in the geologist's way many other obstacles -- rugged terrain, heat, cold, wet, thirst, mosquitos, black flies, etc. Limited time should, of course, be mentioned.
- Because of the above, there is a very strong tendency to infer too much from limited data.

Evans B. Mayo
April, 1977

* Evans B. Mayo, the teacher in the field, with Roger Weller, M.S., University of Arizona, 1972. Photo by George H. Davis, 1970.

EVANS B. MAYO
1902 - 1986

After 21 years of teaching at the University of Arizona, Evans Blakemore Mayo retired to Professor Emeritus status on July 1, 1973. Celebrated for his contributions to structural geology, Dr. Mayo's studies have focused upon the origin of the Tucson Mountains and their volcanic and sedimentary history; the structural evolution of the Santa Catalina Mountains; the structure of the Southern Sierra Nevada, California; and lineament tectonics and its relation to ore districts of the Southwest. Prior to his professorship in 1952 to the Department of Geosciences, when the department was still housed within the College of Mines as the Department of Geology, Dr. Mayo was initially active in the science as an instructor of petrography at Cornell University from 1931-36. He then served as a field geologist for Augustus Locke and Paul Billingsley from 1937-40 and for Kelowna Exploration Company, Ltd., in Hedley, British Columbia, from 1940-41. From 1940-46, he was a resident geologist with the Cotopaxi Exploration Company in Macuchi, Ecuador, and from 1947-52, he acted as exploration geologist and then as chief geologist for Kelowna Exploration in Hedley. He has also served as a consultant to Phelps Dodge Corporation.

Dr. Mayo was born in DeKalb, Illinois, in 1902. He received his bachelor's degree in geology from the University of South Dakota in 1927. In 1929, he completed a master's degree in geology at Stanford University, and in 1932 at Cornell University, he received a doctoral degree in petrography. He was a fellow of the Geological Society of America and of the American Association for the Advancement of Science, a charter member of the Arizona Academy of Science, and a member of the Arizona Geological Society. On January 3, 1986, Dr. Mayo died of a heart attack in Tucson, Arizona.

PUBLICATIONS OF EVANS B. MAYO

- 1929 Stratigraphy and structure of a portion of the eastern escarpment of the Sierra Nevada (abstracts). *Pan-Am Geologist* 51(5): 365. *Geol Soc Am Bull* 41(1): 145, March, 1930.
- 1930 Preliminary report on the geology of the southwestern Mono County, Calif. *Mining in California* 26(4): 475-482. 3 figs, incl map.
- 1931 Fossils from the eastern flank of the Sierra Nevada, Calif. *Science* n.s., 74: 514-515.
- 1932 Two new occurrences of piedmontite in California. *Am Mineralogist* 17(6): 238-248. 3 figs.
- 1933 Discovery of piedmontite in the Sierra Nevada. *Calif Jour Mines and Geol* 29(1,2): 239-243. 3 figs.
- 1934 Geology and mineral deposits of Laurel and Convict Basins, southwestern Mono County, Calif. *Calif Jour Mines and Geol* 30(1): 79-87. 4 figs, incl map, 2 pls, geol and sketch maps.
- 1934 (with William Joseph O'Leary). Oligonite, a manganosiderite from Leadville, Colorado. *Am Mineralogist* 19(7): 304-308. 2 figs.
- 1934 The Pleistocene Long Valley Lake in eastern California. *Science* n.s., 80(2065): 95-96.
- 1934 Preliminary survey of an intraseptum intrusion in eastern California (abstract). *Geol Soc Am Proc* 1933, p. 97.
- 1935 (with Charles Merrick Nevin). Nature and genesis of batholiths (abstract). *Geol Soc Am Proc* 1934, p. 101.
- 1935 Some intrusions and their wall rocks in the Sierra Nevada. *Jour Geol* 43(7): 673-689. 4 figs, incl geol map.
- 1936 Some recent studies of Sierra Nevada pluton (abstract). *AGU, Trans 17th Annu Meet, Pt 1*: 256. *Nat Research Council*.
- 1936 (with Louis Cowles Conant and Joseph Rudolph Chelikowsky). Southern extension of the Mono Craters, Calif. *Am Jour Sci* 5th ser, 32(188):81-97. 6 figs, incl maps.
- 1937 Sierra Nevada pluton and crustal movement. *Jour Geol* 45(2): 169-192. 6 figs, incl geol and index maps. February-March 1937; abstract, *Geol Soc Am Proc* 1937, p. 98, 249, 1938.
- 1939 Deformation in the Sierra Nevada, Calif (abstract). *Geol Soc Am Bull* 50(12), pt 2: 1921.
- 1939 Structural problems in the Sierra Nevada region (abstract). *Geol Soc Am Bull* 50(12), pt 2: 1955-1956.
- 1941 Deformation in the interval Mt. Lyell-Mt. Whitney, California. *Geol Soc Am Bull* 52(7): 1001-1084. Illus incl index, geol maps.
- 1944 Rhyolite near Big Pine, California. *Geol Soc Am Bull* 55(5): 599-619. Illus.
- 1947 Structure plan of the southern Sierra Nevada, California. *Geol Soc Am Bull* 58(6): 495-504. Illus, geol map.
- 1950 Volcanic geology of Toowa Valley, southern Sierra Nevada, California: Discussion. *Geol Soc Am Bull* 61(9): 1021-1022.
- 1951 (with William A. Hogg). Orange Footwall "sill," Nickel Plate mine (British Columbia). *Canadian Min Metall Bull* 469: 325-328. Illus. *Canadian Inst Mining and Metallurgy Trans* 54: 211-214, illus, 1951.
- 1956 Copper, p. 19-32 + maps, in *Mineral Resources Navajo-Hopi Indian Reservations, Arizona-Utah*, volume 1. Tucson: University of Arizona Press.

- 1956 (with J.C. Haff and H.E. Krumlauf). Manganese, p. 39-47 + maps, illus, in Mineral Resources Navajo-Hopi Indian Reservations, Arizona-Utah, volume 1. Tucson: University of Arizona Press.
- 1956 (with sections by S.C. Brown, J.C. Staff, H.S. Haskell, H.E. Krumlauf, E.B. Mayo, D.B. Sayner, and C. Wollman). Metalliferous minerals and mineral fuels -- geology, evaluation, and uses, and a section on the general geology, volume 1 of Mineral Resources, Navajo-Hopi Indian Reservations, Arizona-Utah. 75p. Illus incl geol maps. Tucson: University of Arizona Press.
- 1958 Intrusions near Arizona-Sonora Desert Museum. Ariz Geol Dig 1: 16.
- 1958 Lineament tectonics and some ore districts of the Southwest: Min Mngr 10(11): 1169-1175. Illus. AIME Trans 1958, 211: 1959; discussion by D.L. Evans and reply by author, Min Eng 11(6): 612, 1959.
- 1959 Banerjee's study of the Oracle granite (abstract). Geol Soc Am Bull 70(12): 1735.
- 1959 Recent concepts of ore localization in southern Arizona (abstract). Geol Soc Am Bull 70(12): 1735.
- 1959 Volcanic geology of the northern Chiricahua Mountains. Ariz Geol Soc Guidebook 2 Southern Ariz: 135-138. Illus, incl geol map.
- 1961 Structure of the large phenocryst porphyry near Arizona-Sonora Desert Museum. Ariz Geol Soc Dig 4: 1-17.
- 1963 Volcanic orogeny of the Tucson Mountains (a preliminary report). Ariz Geol Soc Dig 6: 61-82.
- 1964 (with E.J. McCullough, Jr.). Emplacement of basement blocks in the Tucson Mountain Chaos near Tucson, Arizona. Ariz Acad Sci Jour 3(2): 81-86.
- 1964 Folds in gneiss beyond north Campbell Avenue, Tucson, Arizona. Ariz Geol Dig 7: 123-145.
- 1966 Paleocurrents in the Museum Embayment, Tucson Mountains, Arizona. Ariz Acad Sci Jour 4(2): 75-80.
- 1967 Exposures in a wash west of Gates Pass, Tucson Mountains, Arizona. Ariz Acad Sci Jour 4(4): 203-214.
- 1967 Preliminary report on a structural study in the Museum Embayment, Tucson Mountains, Arizona. Ariz Geol Soc Dig 8: 1-32. Illus. (1966); (abstract): Geophys Abs, no 248, item 198.
- 1968 A history of geologic investigation in the Tucson Mountains, Pima County, Arizona, p.155-170 + illus, in Southern Arizona Guidebook 3. Geol Soc Am, Cordilleran Section, 64th Annu Meet. Tucson: Arizona Geological Society.
- 1968 (with P.E. Damon and D.L. Bryant). Stratigraphic and volcanic geology, Tucson Mountains, Field Trip 5, p. 339-350 + illus, in Southern Arizona Guidebook 3. Geol Soc Am, Cordilleran Section, 64th Annu Meet. Tucson: Arizona Geological Society.
- 1968 (with E.S. Davidson, W.E. Elston, F.J. Kuellmer, D. Marjaniemi, D.W. Peterson, M.F. Sheridan, E. Gillerman). Volcanic geology, southwestern New Mexico and southeastern Arizona, field trip 1. Ariz Geol Soc, Southern Arizona Guidebook 3: 243-314. Illus.
- 1969 Fragmental diapir, Piedmontite Hills, Tucson Mountain Park, Arizona. Ariz Acad Sci Jour 5(4): 232-239.
- 1971 Defense of "Volcanic orogeny." Ariz Geol Soc Dig 9: 39-60. Illus, incl geol sketch maps.
- 1971 Feeders of an ash flow sequence on Bren Mountain, Tucson Mountain Park, Arizona. Ariz Geol Dig 9: 137-170. Illus, incl geol sketch map.

**GRADUATE STUDENTS OF EVANS B. MAYO
1952-1976***

- L. Clark Arnold, Ph.D., 1971, structural geology.
- Seid M. Assadi, M.S., 1964, structural geology.
- Anil K. Banerjee, Ph.D., 1957, structural geology-petrology.
- C.S. Venable Barclay, M.S., 1968, geology.
- Richard L. Burroughs, M.S., 1959, structural and economic geology.
- Richard D. Champney, M.S., 1962, structural geology.
- Eugene V. Ciancanelli, M.S., 1965, structural geology.
- Robert E. Colby, M.S., 1958, stratigraphy-structural geology.

Rolfe C. Erickson, M.S., 1962, petrology-structural geology.

Carl Fries, Jr., Ph.D., 1958, geology.

Peter A. Geiser, (M.S., 1965), structural geology-petrology.

Gerald Greenstein, M.S., 1961, structural geology.

Gordon E. Gumble, M.S., 1962, structural geology.

James B. Imswiler, M.S., 1959, structural geology.

Louis Jansen, M.S., 1973, structural geology.

J.P. Jemmett, M.S., 1966, geology.

William W. Jenney, Jr., Ph.D., 1968, structural geology.

Jimmie E. Jinks, M.S., 1961, structural geology.

Louis H. Knight, Jr., M.S., 1967, structural geology.

Earl M.P. Lovejoy, Ph.D., 1964, structural geology.

Edgar J. McCullough, Jr., Ph.D., 1967, structural geology.

Fred Pashley, Ph.D., 1966, structural geology.

H. Wesley Peirce, Ph.D., 1962, stratigraphy.

Richard C. Peterson, M.S., 1963, Ph.D., 1968, structural geology.

William R. Seager, Ph.D., 1966, geology.

James E. Sharp, M.S., 1969, structural and economic geology.

Donald W. Tarman, Ph.D., 1975, structural geology.

Dee D. Trent, Ph.D., 1973, structural geology.

Charles J. Waag, Ph.D., 1968, structural geology.

Roberts M. Wallace, Ph.D., 1955, structural geology.

Richard R. Weaver, M.S., 1965, structural geology.

* We have made a sincere attempt to prepare a complete list of graduate students under the direction of Dr. Mayo. Please accept our apologies for any name we may have missed and let us know of the omission, at the Department of Geosciences, University of Arizona, Tucson, Arizona, 85721.



**POSTSCRIPT, FROM NOTES DISCOVERED BY TECTONICS STUDENT MARGARET KLUTE
ON JANUARY 16, 1986**

It makes good sense to know as much as possible about what one tries to explain, yet a great mass of data does not guarantee the desired truth. I have known students to collect many facts, yet reach no conclusion -- or the wrong conclusion. Diligence is admirable, but intelligence helps too and luck is definitely a factor.

A natural human laziness may preclude acquiring sufficient observations, but even more ominous is an intense desire to force the facts into a preconceived pattern. One should never "drive" the data but follow them to see into what pattern they prefer to fit.

An old friend, who died many years ago, once said: "The life of a geologist is a dialogue between himself and nature, and it always results that nature is the smarter." That word always is most important. There are no exceptions.

Evans B. Mayo
April, 1977

**THE EVANS B. MAYO ENDOWED FELLOWSHIP
IN STRUCTURAL GEOLOGY**

In the fall of 1979, an anonymous alumnus of the Department of Geosciences at the University of Arizona donated stock for conversion to cash toward the establishment of the Evans B. Mayo Endowed Fellowship in Structural Geology. This cash has been invested by the Arizona Foundation, and proceeds from the current principal are expected to provide an annual fellowship to be awarded to graduate students, master's or doctoral candidates, for field work in structural geology. The department hopes to generate additional donations allowing the stipend to support a student for one year at a rate of \$5000 or more. The fellowship fund is administered by the faculty of the department.

Our geoscientists of tomorrow need your help today. Your support of the Evans B. Mayo Endowed Fellowship in Structural Geology will ensure the continuing annual support of these young scientists and at the same time, will increase the principal of the fund, allowing us to award larger fellowships to a greater number of students. Donations may be sent to:

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in Structural Geology
Department of Geosciences
University of Arizona
Tucson, Arizona 85721

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Foreward

This Digest is the proceedings of the symposium "Frontiers in Geology and Ore Deposits of Arizona and the Southwest" held at The University of Arizona in Tucson on March 20-21, 1986. Associated field trips were held March 17-19 and 21-23. The symposium was sponsored by the Arizona Geological Society.

The conference was designed to provide an arena for presentation and discussion of recent work on the geology and ore deposits of Arizona, southwestern California, New Mexico, and Mexico. Fresh insights into the geology of the region, covering the full spectrum of geologic time, were presented at the conference and are included in this volume.

This volume, originally intended to include only extended abstracts of talks presented at the symposium, was expanded to include full papers, field trip road logs, and poster session abstracts. Speakers and field trip leaders were specifically invited to the conference and were requested to submit manuscripts for this Digest. Anyone doing research in this region who wanted to display that work in a poster session was allowed to do so and also to submit an abstract or article for publication.

All manuscripts were submitted to the Arizona Geological Society in camera-ready format; the authors are solely responsible for their content. Any peer review, if conducted, was done at the initiation of the authors and/or their organizations.

Acknowledgments

Members of the symposium committee and members-at-large of the Arizona Geological Society thank all symposium participants for their interest and support without which this volume could not have been produced. Special thanks to all the typists and artists who prepared the text, drafted the figures, and pasted up the copy on the format pages.

Thanks are also in order to H. R. Hauck, who provided useful editorial assistance. Additionally, several members of the Arizona Bureau of Geology and Mineral Technology were very helpful in assisting with various aspects of the publication of this Digest.

A special thank you to both Will Wilkinson and Steve Reynolds for their valuable insights and advice regarding innumerable important details connected with this publication.

Barbara Beatty and P. A. K. Wilkinson
Editors

Tucson, Arizona
January 1986

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